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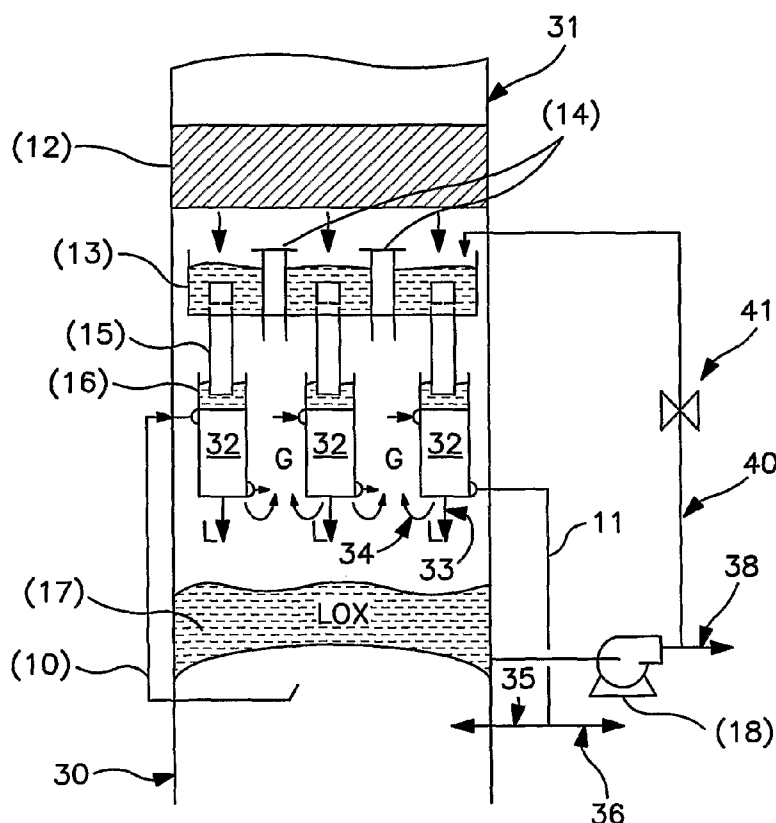
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(54) **Title:** MAIN CONDENSER FOR CRYOGENIC AIR SEPARATION SYSTEM



(57) **Abstract:** A cryogenic air separation system having a main condenser (32) comprising a plurality of tubes having fluted external condensing surfaces (45) upon which downf lowing nitrogen vapor condenses, and having structured internal boiling surfaces (46) upon which downf lowing oxygen liquid vaporizes. The main condenser (32) can be employed as a condenser/reboiler located within a lower pressure column (31) to condense nitrogen vapor from a higher pressure column (30) and partially vaporize oxygen liquid within the lower pressure column (31) .



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MAIN CONDENSER FOR CRYOGENIC
AIR SEPARATION SYSTEM

Technical Field

[0001] This invention relates generally to cryogenic air separation and, more particularly, to cryogenic air separation employing a double column.

Background Art

[0002] Cryogenic air separation systems employing downflow main condensers with high flux tubes, while operating effectively, may exhibit one or more disadvantages. One disadvantage is the high cost associated with the porous coating. In addition, any non-uniformity of the porous coating could result in variations in the boiling performance.

Summary Of The Invention

[0003] One aspect of the present invention is:

[0004] A method for operating a cryogenic air separation plant having a higher pressure column, a lower pressure column, and a main condenser having a plurality of tubes wherein each of said tubes has a fluted external surface and a structured internal surface, said method comprising passing nitrogen vapor from the higher pressure column to the upper portion of the main condenser, flowing oxygen liquid from the separation section of the lower pressure column to the upper portion of the tubes of the main condenser, passing the nitrogen vapor down the main condenser in contact with the external surfaces of the tubes, passing the oxygen liquid down the tubes of the main

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condenser in heat exchange relation with the downflowing nitrogen vapor wherein at least some but not all of the downflowing oxygen liquid is vaporized, and withdrawing both oxygen vapor and oxygen liquid from the main condenser in a liquid to vapor mass flowrate ratio within the range of from 0.05 to 10.

[0005] Another aspect of the present invention is:

[0006] A downflow condenser, particularly suitable as the main condenser of a double column cryogenic air separation plant, having a plurality of tubes wherein each of said tubes has a fluted external surface and a structured internal surface.

[0007] As used herein, the term "separation section" means a section of a column containing trays and/or packing and situated above the main condenser.

[0008] As used herein, the term "enhanced surface" means a special surface geometry that provides higher heat transfer per unit surface area than does a plain surface.

[0009] As used herein, the term "column" means a distillation or fractionation column or zone, i.e. a contacting column or zone, wherein liquid and vapor phases are countercurrently contacted to effect separation of a fluid mixture, as for example, by contacting of the vapor and liquid phases on a series of vertically spaced trays or plates mounted within the column and/or on packing elements such as structured or random packing. The term, double column is used to mean a higher pressure column having its upper end in heat exchange relation with the lower end of a lower pressure column.

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[0010] Vapor and liquid contacting separation processes depend on the difference in vapor pressures for the components. The high vapor pressure (or more volatile or low boiling) component will tend to concentrate in the vapor phase whereas the low vapor pressure (or less volatile or high boiling) component will tend to concentrate in the liquid phase. Partial condensation is the separation process whereby cooling of a vapor mixture can be used to concentrate the volatile component(s) in the vapor phase and thereby the less volatile component(s) in the liquid phase. Rectification, or continuous distillation, is the separation process that combines successive partial vaporizations and condensations as obtained by a countercurrent treatment of the vapor and liquid phases. The countercurrent contacting of the vapor and liquid phases is generally adiabatic and can include integral (stagewise) or differential (continuous) contact between the phases. Separation process arrangements that utilize the principles of rectification to separate mixtures are often interchangeably termed rectification columns, distillation columns, or fractionation columns. Cryogenic rectification is a rectification process carried out at least in part at temperatures at or below 150 degrees Kelvin (K).

Brief Description Of The Drawings

[0011] Figure 1 is a simplified representational schematic diagram of one preferred embodiment of the cryogenic air separation system of this invention.

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[0012] Figure 2 is a partial cut away view of one embodiment of a doubly enhanced tube which may be used in the practice of this invention.

[0013] Figures 3 and 4 each illustrate preferred structured boiling surfaces, in highly magnified side views, which may be employed as the internal surface of the tubes of the downflow main condenser in the practice of this invention. Presently, these surfaces are commercially manufactured on the external surfaces of tubes.

Detailed Description

[0014] The invention comprises a novel heat exchanger having defined doubly enhanced tube surfaces, and its use as the main condenser in a double column cryogenic air separation plant. The tubes are characterized by having both enhanced boiling surfaces and enhanced condensing surfaces. The enhanced condensing surfaces comprise flutes for at least a portion of the length of the tubes. The enhanced boiling surfaces are structured surfaces. A structured boiling surface is an enhanced boiling surface formed by metal working to form nucleation sites on the heat transfer surface characterized by a plurality of cavities that trap vapor and initiate boiling at low wall superheats.

[0015] The invention will be described more fully with reference to the Drawings. Referring now to Figure 1, there is shown a partial schematic of a double column cryogenic air separation plant, having a higher pressure column 30 and a lower pressure column 31, and showing the placement of main condensers 32,

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also referred to as condenser/reboilers, inside the lower pressure column. The main condenser(s) of this invention may be of the shell and tube type or of the brazed aluminum heat exchanger type. The main condenser/reboilers thermally link the higher pressure and lower pressure columns. Nitrogen vapor, at a pressure generally within the range of from 45 to 300 pounds per square inch absolute (psia), is passed in line 10 from higher pressure column 30 to the upper portion of the main condenser or condensers wherein the nitrogen vapor exchanges heat with oxygen liquid within the tubes as both fluids flow down through the main condenser(s). The oxygen liquid, which is at a pressure generally within the range of from 1 to 100 pounds per square inch gauge (psig) is partially vaporized and the resulting oxygen vapor and remaining oxygen liquid are withdrawn from the main condensers(s) as shown by flow arrows 34 and 33 respectively. The nitrogen vapor is completely condensed by the downflow passage through the main condenser and the resulting nitrogen liquid is withdrawn from the main condenser in line 11 and passed in lines 35 and 36 respectively as reflux into the higher pressure and lower pressure columns.

[0016] In the lower pressure column 31, oxygen liquid descending the column through packing 12 or trays (not shown) is collected in collector/distributor 13. Open risers 14 extend up from the floor of the collector box for the oxygen vapor generated in the main condenser to flow up through the column. Oxygen liquid from the collector flows through distributor pipe 15 and collects in the distributor section 16 of

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the individual modules. The oxygen liquid from the flow distributor section flows through the individual tubes where it is partially vaporized. These passages have enhanced boiling surfaces, i.e. structured internal surfaces, which significantly increases the ability of the liquid to wet the surface of the boiling side and reduces the amount of liquid flow needed to achieve wetting. The unvaporized liquid 17 collects at the bottom of the column and is withdrawn from the column as a product in line 38. The product boiler pump 18 is used to raise the pressure of oxygen to the required product pressure. If desired, a portion 40 of stream 38 may be passed through valve 41 and recirculated to the main condenser(s). The ratio of liquid to vapor mass flowrate (L/V) at the exit of the main condenser tubes or vaporizing passages ranges from 0.05 to 10, and is preferably within the range of from 0.2 to 2.0.

[0017] Each condenser/reboiler 32 comprises a plurality of longitudinally oriented tubes that are attached, usually by welding, to a top tubesheet and a bottom tubesheet in the case where the main condenser is a shell and tube heat exchanger. The tubesheets are not shown in Figure 1. Each tube has an internal surface and an outer surface. The external surface of each tube is fluted, i.e. it has a plurality of flutes running along the length, preferably the entire length, of the tube to enhance the condensation heat transfer. The nitrogen vapor flows downwardly over the tubes and is condensed, preferably completely condensed, by the time it traverses the length of the tubes. The resulting condensate, i.e. nitrogen liquid, is

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withdrawn from the bottom exits of the shell side. The nitrogen liquid is passed out of the condenser/boilers 32 in conduit 11 and is passed into the upper portion of the higher pressure column and also into the upper portion of the lower pressure column as reflux liquid for carrying out the cryogenic rectification. For simplicity, only one of the connections from the condenser/reboilers 32 to line 11 is shown in Figure 1. If desired, a portion of the nitrogen liquid may be recovered as product nitrogen.

[0018] The inner surface of each tube has an enhanced or structured boiling surface characterized by a plurality of cavities or depressions which have a depth generally within the range of from 0.5 to 2.0 millimeters. Two examples of such cavities are shown in cross-section in Figures 3 and 4. The enhanced boiling surface with the re-entrant cavities operates by trapping vapor within the cavities for initiating boiling at low tube wall superheats, which is defined as the temperature difference between the tube wall surface and the saturation temperature of the fluid to be vaporized. The oxygen liquid flows downwardly along the inner surfaces of the tubes in cocurrent indirect heat exchange with the previously described downflowing condensing nitrogen vapor. As the oxygen liquid flows down along the enhanced boiling inner surfaces of the tubes, a portion of the downflowing oxygen liquid is boiled off or vaporized, as shown by arrows G in Figure 1, while the remaining liquid, shown by arrows L in Figure 1, is collected in the sump of the upper column as shown by liquid pool 17. The oxygen vapor boiled off the inner surfaces of the tubes passes up through

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the upper column as vapor upflow for the cryogenic rectification. If desired a portion of the oxygen vapor may be recovered as product gaseous oxygen. If desired a portion of the remaining oxygen liquid 17 may be recovered as product liquid oxygen. Alternatively, the remaining oxygen liquid 17 is recirculated to the tubes in order to ensure that the boiling surfaces of the tubes remain wet, thereby avoiding a boiling to dryness condition which is inefficient and, when the liquid comprises liquid oxygen, is also dangerous. For the recirculation flow, oxygen liquid 17 is withdrawn from the upper column 31 and pumped by liquid recirculation pump 18.

[0019] Typically in the practice of this invention the tubes will have an internal diameter within the range of from 15 to 25 millimeters. Figure 2 illustrates a doubly enhanced tube for use with this invention which has a fluted external surface 45 and a structured internal surface 46. The condenser will typically contain from about 300 to 800 such tubes. It may also contain one or more other tubes which are not characterized by having such doubly enhanced surfaces. Figures 3 and 4 show side views of two typical embodiments of structured boiling surfaces for use with this invention. The surface shown in Figure 3 is commercially known as GEWA surface. The shape of the cavity is called double reentrant cavity and traps vapor very effectively. The surface shown in Figure 4 is typical of Wolverine Turbo-B™ tubes. Fins are first formed on the surface and they are modified by cold working to give the desired shape of the cavities.

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[0020] Although the invention has been described in detail with reference to certain preferred embodiments, those skilled in the art will recognize that there are other embodiments of the invention within the spirit and the scope of the claims.

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CLAIMS

1. A method for operating a cryogenic air separation plant having a higher pressure column, a lower pressure column, and a main condenser having a plurality of tubes wherein each of said tubes has a fluted external surface and a structured internal surface, said method comprising passing nitrogen vapor from the higher pressure column to the upper portion of the main condenser, flowing oxygen liquid from the separation section of the lower pressure column to the upper portion of the tubes of the main condenser, passing the nitrogen vapor down the main condenser in contact with the external surfaces of the tubes, passing the oxygen liquid down the tubes of the main condenser in heat exchange relation with the downflowing nitrogen vapor wherein at least some but not all of the downflowing oxygen liquid is vaporized, and withdrawing both oxygen vapor and oxygen liquid from the main condenser in a liquid to vapor mass flowrate ratio within the range of from 0.05 to 10.

2. The method of claim 1 wherein the liquid to vapor mass flowrate ratio is within the range of from 0.2 to 2.0.

3. The method of claim 1 wherein the main condenser is a shell-and-tube heat exchanger.

4. The method of claim 1 wherein the main condenser is a brazed aluminum heat exchanger.

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5. The method of claim 1 wherein the main condenser comprises a plurality of condenser modules.

6. A downflow condenser, particularly suitable as the main condenser of a double column cryogenic air separation plant, having a plurality of tubes wherein each of said tubes has a fluted external surface and a structured internal surface.

7. The condenser of claim 6 having from 300 to 800 tubes.

8. The condenser of claim 6 wherein the structured internal surface has cavities with a depth within the range of from 0.5 to 2.0 millimeters.

9. The condenser of claim 6 wherein the tubes have an internal diameter within the range of from 15 to 25 millimeters.

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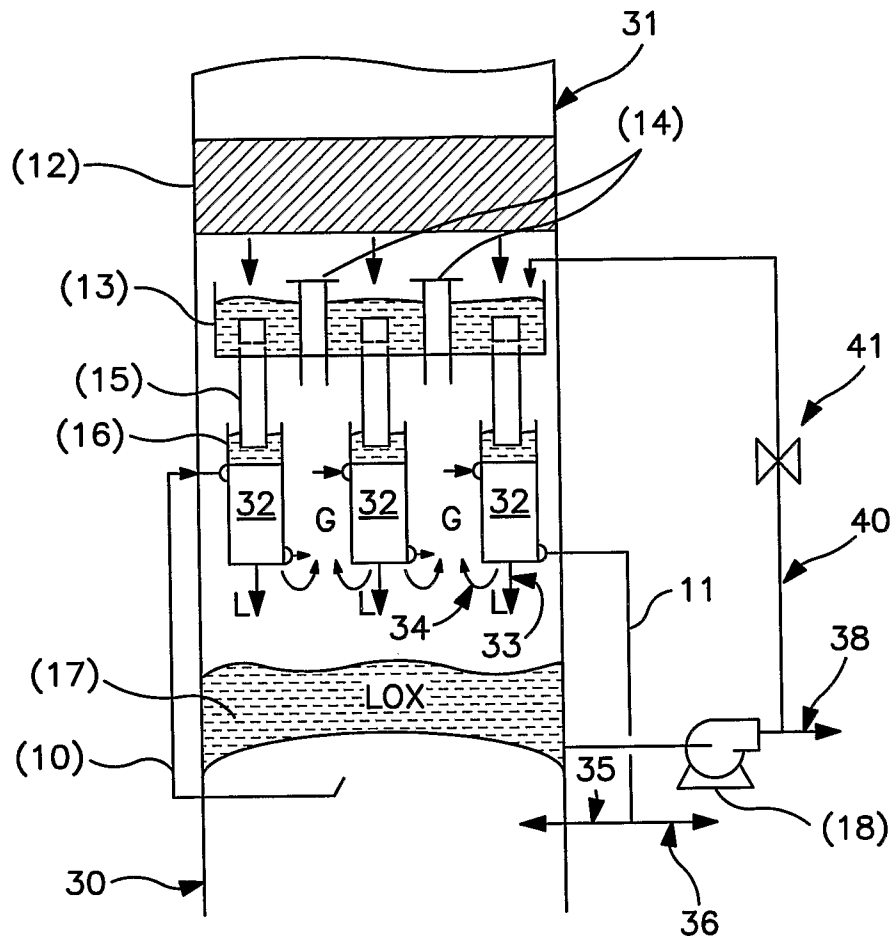


FIG. 1

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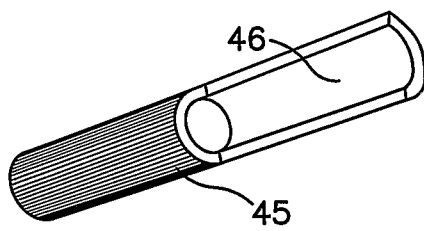


FIG. 2

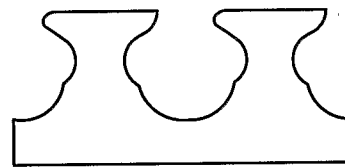


FIG. 3

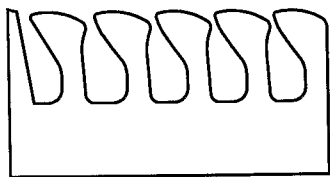


FIG. 4